The Law of Conservation of Momentum

Recall Physics 11: you learned (and perhaps forgot?) that the sum of momentums of all objects before an event such as an explosion or a collision = the sum of momentums of all objects after the event has occurred. Even though momentum is a vector quantity, this was an easy task, since only motion in a straight line was considered.

Formally, the Law of Conservation of Momentum states that the total vector momentum of all bodies before an event = the total vector momentum of all the bodies after the event. As with all vector problems in this course, components need to be considered in order to deal with this situation.

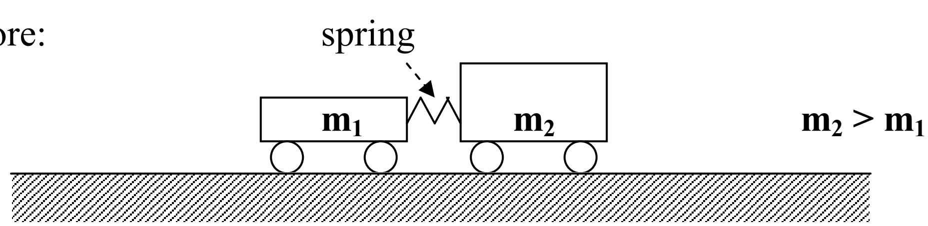
For now, we'll review the positive-negative types of momentum from Physics 11.

Explosions

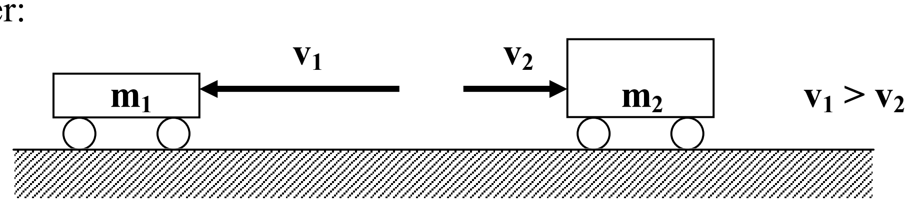
In an explosion involving a system that is initially stationary, the total momentum before the explosion event is zero. Therefore, the vector adding of all particles after the explosion must also = 0.

When only 2 particles explode apart, they must move in opposite directions along the same straight line. This is because the momentum of one particle must be opposite to the momentum of the other particle. Note that if one particle is larger than the other, its opposing velocity must be smaller than the other.

- Before:



- After:



total momentum before = total momentum after, so

$$0 = m_1v_1 + m_2v_2$$

Example #8: A 3.5 kg cart explodes away from a 5.0 kg cart at 2.0 m/s. What is the velocity of the larger cart?

(see Momentum Ex 8 for answer)

Example #9: The nucleus of a certain atom has a mass of 3.8×10^{-25} kg and is at rest. The nucleus is radioactive and ejects a particle of mass 6.6×10^{-27} kg and speed 1.5×10^{7} m/s. Find the recoil velocity of the remaining nuclear mass left behind.

(see Momentum Ex 9 for answer)

<u>Collisions (still one-dimensional motion)</u>

There are numerous types of collision problems to consider; some examples are shown below. Note that <u>negative</u> velocities must be indicated when objects approach from opposite directions, or change directions because of the impact.

- For a moving object colliding with a stationary object, the moving object $\mathbf{m_1}$ has the only momentum before the collision, and both objects (usually) have momentum after the collision.

total momentum before = total momentum after

$$\mathbf{m_1 v_1 = m_1 v_1' + m_2 v_2'}$$

Example #10: A 3.0 kg lab cart going 15 m/s runs into a 10 kg stationary lab cart so that it takes a speed of 6.0 m/s. What is the velocity of the 3.0 kg lab cart after the collision?

(see Momentum Ex 10 for answer)

- When both objects are moving before the collision, they both have a 'before' momentum. This is true when one object catches up to and rear-ends another, or when both objects collide head-on. If both objects bounce off each other after the collision, each one will have an 'after' momentum.

total momentum before = total momentum after

$$\mathbf{m_1 v_1 + m_2 v_2 = m_1 v_1' + m_2 v_2'}$$

Example #11: A 2.0 kg lab cart moving at 3.0 m/s catches up to and rear ends a 1.0 kg cart moving at 0.50 m/s. After the collision, the 2.0 kg cart follows the 1.0 kg cart at 1.2 m/s. Find the new velocity of the 1.0 kg cart.

(see Momentum Ex 11 for answer)

- When two objects collide in a completely *inelastic* collision, they will stick and move off together, acting as a single, combined mass.

total momentum before = total momentum after

$$\mathbf{m_1v_1 + m_2v_2 = (m_1 + m_2)v'}$$

→where **v'** is the common velocity after the collision.

Example #12: A 5000. kg truck going at 15 m/s makes a head on collision with a 1000. kg Honda that was going 20 m/s. The wreckage sticks together. Find the velocity of the wreckage just after the collision.

(see Momentum Ex 12 for answer)